Before the

Federal Communications Commission

Washington, DC 20554

In the Matter of	)	
	)	
Carrier Current Systems, including Broadband over Power Line Systems	))	ET Docket No. 03-104
	)	
Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems	)))	ET Docket No. 04-37

ARINC Petition For Reconsideration

Aeronautical Radio, Inc. ("ARINC"), pursuant to Section 1.429 of the Commission's Rules, 47 C.F.R. § 1.429, respectfully seeks limited reconsideration of the Commission's *Report & Order,* FCC- 04-245, released October 28, 2004, in this proceeding ("*Report & Order*").

For the reasons set forth below and in Appendix A hereto, ARINC urges that the exclusion from BPL operations of Aeronautical Mobile (R) frequencies and the 74.8 – 75.2 MHz Aeronautical Navigation frequencies include Access BPL systems operating on overhead low voltage power lines and In-House BPL systems in addition to Access BPL systems operating on overhead medium voltage lines. ARINC also urges the Commission to reconsider the mitigation requirements, the measurement procedures for BPL, and to make minor changes in the rules pertaining to consultations prior to commencement of BPL operations.

Background

ARINC commends the Commission for addressing the technically complex matter of how to permit power lines to be used to transmit broadband radio frequency energy for internet access. The *Report and Order* adopted regulations that, with minimal changes, should provide an effective framework for implementing BPL while, at the same time, safeguarding the communications and radio navigation services that are critical to the safe and efficient operation of the nation's air transport system.

ARINC, the communications company of the air transport industry, participated actively in this proceeding to ensure that the benefits of BPL could be realized without causing harmful interference to aviation safety services. In the HF aeronautical mobile (R) spectrum ARINC provides high frequency single side band aeronautical operational control (AOC) and air traffic control (ATC) communications[1] for aircraft flying over the Atlantic, Caribbean, and Pacific oceans; Canadian and Arctic regions; the Gulf of Mexico; and Central and South America. ARINC's HF long distance operational control (LDOC) facilities provide worldwide coverage. ARINC connects the far-reaching corners of the world to one of two ARINC Communications Centers located in New York and San Francisco. The ARINC Communication Centers use these HF facilities to relay ATC flight movement messages for the FAA while aircraft are flying in oceanic flight information regions ("FIRs") assigned to the FAA.[2]

The Nature of Aeronautical HF Service

As ARINC explained earlier in this proceeding, the trained radio operators who staff aeronautical HF ground stations must often communicate with distant aircraft at signal levels that are at or even below the noise floor. Accordingly, ARINC submits that the statement at Paragraph 51 of the *Report and Order* that a "properly designed and operated Access BPL system will pose little interference hazard to services such as aeronautical, maritime and public safety that are

[1] This service is used to coordinate ground and flight activities, inform aircraft dispatchers of important events including in-flight emergencies, address irregular operations such as delays and the need for more fuel due to weather conditions, make ground arrangements for the servicing of aircraft, divert aircraft, and provide timely position reports for flight following. U.S. air carriers are required to have access to AOC throughout the world by 14 C.F.R. § 121.99. Both aeronautical operational control and air traffic control are safety services and are entitled to special measures to avoid interference under the International Radio Regulations. *See* ITU RR 1.33, 1.59, and 4.10.

[2] The vast majority of the voice messages over ARINC's HF stations are FAA ATC, flight following, and way-point reporting; about 10,000 per month are LDOC.

designed to operate with relatively high signal-to-noise ratios" reflects a serious misunderstanding that is at odds with the reality of aeronautical HF operation and the record in this rule making. To be sure, the limited number of aeronautical HF ground stations use sophisticated receiving equipment and generally operate from relatively low noise locations. These ground stations, however, are receiving extremely weak signals often propagated over many hundreds, if not thousands, of miles by aircraft stations of modest power using relatively inefficient transmitting antennas necessitated by the physical realities of aircraft design and operation.[3]

To make use of weak signals, aeronautical stations select frequencies that are optimum or nearly optimum for the time of day during which the communications will occur. Even so, the signals that arrive at ARINC communications centers are often at or below the noise floor and are usable only because of the skill of the radio operators who employ communications practices that are widely understood and accepted within the aviation community.[4] The assumption that aeronautical HF systems will operate with "relatively high signal-to-noise" ratios is simply inaccurate and not supported by the record in this proceeding. As such, the Commission's actions on reconsideration should take into account the realities of aeronautical HF communications.

BPL Over Low Voltage Lines

The Commission wisely excluded BPL operations over the aeronautical mobile (R) HF frequencies used by ARINC and the 74.8 – 75.2 MHz aeronautical radio navigation band used by outer marker beacons at airports throughout the country to support instrument landing systems.

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[3] Aircraft face power, weight, and wind loading constraints that limit the complement of HF transmitting and receiving equipment that can be installed.

[4] Aircraft receive stations must also function successfully under less than optimum signal-to-noise conditions due, in part, to relatively inefficient antennas.

Unfortunately, the new rules largely ignore the potential that Access BPL on low voltage lines pose for HF communications and navigation systems.[5]

Additionally, the new rules do not take into account the potential for In-House BPL systems to cause interference to aeronautical HF communications. Indeed, carrier current devices employed to provide for the transmission of telephone communications within a house over the wiring of dwellings appear to have been responsible for the interference documented in ARINC's Reply Comments in this proceeding.[6] These signals were traced to devices operating within homes more than five miles (over 8 km) from an ARINC HF ground station.[7] Indeed, it is now apparent that in-house BPL could prove to be an especially vexing problem because the users of such equipment will have little understanding of its operating parameters, its interference potential, and cannot effectively be required to participate in any accessible registration of their use of the frequencies.

To prevent the possibility of interference to critical aeronautical facilities, the Commission on reconsideration should amend Section 15.615 to prohibit the use of the aeronautical frequencies

[5] The rules would require Access BPL operators to engage in consultations with ARINC prior to initiation of operations on low voltage lines within 4 km of the aeronautical HF ground stations. Most airports, however, would not be within such consultation zones. As such, aircraft testing HF equipment while on the ground and mobile reception would be vulnerable to potential interference from such low voltage BPL systems. Test transmissions and reception at airports are a critical part of each flight in which HF will be used. While HF is not the primary mode of communications for most domestic flights, HF data operations could be required domestically should VHF circuits ever become unavailable. HF voice is also widely used domestically in Alaska. Additionally, ARINC does not operate facilities in the 74.8 – 75.2 MHz aeronautical radio navigation band. Outer marker beacons in instrument landing systems use this VHF band and are operated by airport authorities, the FAA, and the Department of Defense. As such, consultation with ARINC as to low voltage BPL use of this band would not be effective.

[6] ARINC Reply Comments at 8 and Attachment C thereto (June 22, 2004).

[7] While this interference has subsequently been largely mitigated with the cooperation of the Commission, the effort has been expensive. Before the interference on 3013 kHz was substantially reduced, ARINC was forced to change operating frequencies at the site and incurred tens of thousands of dollars in costs associated with engineering, troubleshooting, and the publication of new frequency tables for the aviation community.

for in-house BPL and to prohibit access BPL use of these frequencies on both low voltage and medium voltage overhead lines.

Interference Mitigation Requirements

The Commission elected to require only that BPL equipment providers include provisions for remotely reducing power of devices and adjust operating frequencies "in order to avoid site-specific, local use of the same spectrum by licensed services."[8] The Commission then added that one of the techniques could include "adaptive or 'notch' filtering." If notch filtering is included, as a technique, it must provide attenuation of at least 20 dB below the applicable Part 15 limits for frequencies below 20 dB. A minimum attenuation of 10 dB is required for any notch filter above 30 MHz. Contrary to NTIA's recommendation, the new rules do not specify any minimum bandwidth for notch filtering.

ARINC understands the Commission's desire not to place undue burdens on the flexibility of technology developers to meet the salutary goal of preventing harmful interference to licensed services. At the same time, ARINC urges the Commission to clarify upon reconsideration that activating a 20 dB notch will not necessarily resolve cases of harmful interference and satisfy the BPL operator's obligation under Section 15.5 of the Rules not to cause harmful interference. While the 20 dB notch is significant, there is clearly no guarantee that its use will satisfactorily resolve any particular situation. Indeed, equipment authorization grantees and system operators under various other of the Commission's rules are more typically subject to a requirement to suppress undesired emissions by 43 +10 LogP dB where P equals transmitted power. Nevertheless, the Commission's Rules also often note that if harmful interference occurs, additional suppression will be required.[9] Although ARINC believes that the Commission did not

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[8] Section 15.611(c)(1).

[9] *See e.g.*, Sections 22.359, 24.133(c); 24.238(d), and 73.687(e).

intend to limit the maximum necessary suppression of undesired emissions for BPL to 20 dB across an unspecified bandwidth in response to any interference complaint, the Commission should, upon reconsideration, make clear that while the requirement to incorporate mitigation techniques can be partially satisfied by including the capability to use such a notch, greater suppression may, in fact, be necessary in any particular case if the BPL operator is to comply with the obligations imposed by Section 15.5 of the Commission's Rules.

Measurement Procedures

In its *Report and Order,* the Commission noted the need for an extrapolation factor when measurements could not be made at 3 or at 10 meters.[10] The record showed that the attenuation that would be predicted for HF signals radiated from power lines would not necessarily be characterized accurately by the 40 dB per decade factor set forth currently in the Part 15 Rules, which assumes a point source radiator rather than an extended radiator such as a power line, which behaves more like a line source. The numerical electrical code simulations conducted in preparation for comments in this proceeding revealed that an extrapolation factor of 20 dB per decade would more accurately characterize this attenuation.[11] Nevertheless, the Commission made no change in the regulations and left in place the same 40 dB per decade general factor that is applied across the spectrum. The rationale for this decision appears to rest upon the analysis set forth in the Ameren Reply Comments.[12] Upon reconsideration the Commission should change Section 15.31(f)(2) of the Rules to provide that for BPL systems operating below 30 MHz an extrapolation factor of 20 dB per decade must be used absent a clear showing that a higher factor should apply.

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[10] Report & Order ¶ 109.

[11] See also Appendix A hereto summarizing numerical electrical code analysis performed by ARINC.

[12] Report & Order ¶ 109 (citing the Ameren Reply Comments filed June 22, 2004).

Contrary to the brief discussion in the *Report and Order*, the Ameren Reply comments do not provide a sound basis for using a 40 dB per decade extrapolation factor in making measurements of BPL signals radiated from power lines. On page 9 of its Reply, Ameren discusses figures D-27, D-29, D-31 and D-33 of the NTIA Report 04-413, Volume II. Ameren claims that the fields away from the line have an average decay rate of 40 dB/decade. In reviewing D23, D25, D27, D29, D31 it is apparent the decay is, in fact, much less than 40 dB/decade over most of the curves presented in the five NTIA case studies. The decay rate, in fact, varies greatly and even exhibits signal strengths actually increasing with distance from the radiator. Moreover, Ameran appears to treat the radio frequency field generated by a BPL system as one created by a single frequency rather than a broadband signal covering many frequencies.[13] The broad spectrum band employed by BPL will create nulls and maxima in the radio frequency field that are frequency dependent, and the point where one frequency generates a null will experience a maximum field strength from another frequency.

Ameren goes on to say that "[t]hese figures show that the fields away from the line have an average decay rate of 40 dB/decade. This is in complete agreement with AEC's own theoretical calculations summarized in Fig. 1 below"[14]. Figure 1. of the AEC filing cited by Ameren filling presents six curves representing 3, 15, 30, 40, 60, 80 MHz. All of these theoretical cases predict a 40 dB/decade extrapolation factor at each of these frequencies. Ameren goes on to say that that this Figure 1 of the AEC filing can be "compared with the figures above of the NTIA report, especially, with fig. D33 to verify the satisfactory agreement between the experimental and theoretical results." This is where Ameren's 40 dB/decade conclusions misses the mark. Note that the current Part 15 decay factor for frequencies *above* 30 MHz is 20 dB/decade not 40 dB/decade. The Ameren analysis suggests that for

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[13] Ameran Reply Comments (June 22, 2004) at 8.

[14] *Id.* at 9

frequencies above *and below* 30 MHz the decay factor is 40 dB/decade. This conclusion suggests a significant flaw in Ameren's analysis when comparing their results to NTIA's actual measurements.

Comparison of Ameren's Figure 1. (Ameren's theoretical results) to the NTIA Figures (measured results) D23, D25, D27, D29, D31 and D33 reveals that the decay factor is in fact less than the part 15 $1/R^2$ (20dB/decade) for 35, 39, 45 MHz. NTIA noticed this and commented: "The results indicate that the received power decreases as distance from the power line increases at a rate lower than would be predicted by $1/R^2$ (space wave Loss)."[15] In short, the 20 dB/decade decay figure for frequencies above 30 MHz did not hold true. NTIA then reinforced this conclusion by concluding that "[a] modified distance extrapolation factor should be applied for BPL systems that reflects realistic decay in field strength with increasing distance. The extrapolation factors assumed in Part 15 appear to be unrealistic for BPL systems (40 dB/decade and 20 dB/decade below and above 30 MHz, respectively)."[16]

For frequencies below 30 MHz, NTIA figures D23, D25, D27, D29, D31 show decay values much less than 40 dB/decade. Indeed, these are as little as 10 dB/octave and more like 15 to 20 dB/decade. As such, ARINC submits that the NTIA measured results are more in line with a 20 dB/decade extrapolation factor as suggested earlier by ARINC based on the analysis that ARINC engineer Joel Fox performed for frequencies below 30 MHz. For point source radiators, the Commission has heretofore permitted extrapolation factors other than those set forth in the rules on the basis of clear and convincing measurement data showing that the 40 dB/decade factor is inapplicable in specific circumstances. In the case of Access BPL, the record actually shows that a 20 dB/decade factor should apply. As such, the Commission should amend Section 15.31 to require the use of 20 dB/decade in BPL measurements absent a clear and convincing showing that a greater factor should apply.

Consultation Areas

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[15] NTIA Report 04-413, vol. II, D-34.

[16] *Id.* vol. I, at 9-6, 9-7; see also *id*. at 9-9 ("Topics for Further Study").

ARINC appreciates the effort that the Commission expended in developing the new rules involving consultation areas. ARINC has rechecked the coordinates for the receive sites listed in the rule and has determined that the coordinates originally supplied to the Commission contained errors that should be corrected. The following coordinates should be changed:

Location Name	Latitude	Longitude
Half Moon Bay, CA	37° 39' 64"	122° 24' 44"
Barrow, AK	71° 17' 24"	156° 40' 12"
Guam	13° 28' 12"	144° 48' 0.0"

In addition, the email address for notifications should also be revised in order that such notifications not be intermixed with communications pertaining to the marketing of ARINC services. To this end, ARINC is establishing the following address:

bplnotifications@arinc.com

Use of this address will allow notifications to be forwarded automatically to those ARINC personnel involved with the management and maintenance of the HF network in order that any needed dialog can be initiated promptly with BPL system operators. Section 15.615 if the Rules should be changed to reflect these requested modifications.

Finally, the Commission recognized in the case of U.S. Coast Guard facilities that circumstances may dictate the relocation of such facilities and that in the unlikely event this occurs, BPL operators will need to cooperate with the Coast Guard in facilitating such a move.[17] ARINC, too, may face situations requiring such changes. Upon reconsideration, ARINC urges the Commission to note that should such changes be necessary BPL operators must cooperate in facilitating the change if adjustments in BPL system parameters are needed in order to assure continued operation of the HF aeronautical facilities without interference from BPL operations. While ARINC would expect that such changes will not be frequent, reconsideration presents an

[17] Section 15.615(f)(2)(ii) of the Rules.

opportunity for the Commission to clarify this obligation and to delegate to the Chief of the Office of Engineering and Technology authority to modify Section 15.615, Table 3a, accordingly.[18]

Conclusion

The Commission's *Report and Order* adopting rules for the implementation of BPL represents a substantial achievement in facilitating the growth of a new broadband communications medium while trying to protect essential safety services. ARINC stands willing to work with the Commission and the BPL community as BPL systems are deployed. At the same time, ARINC respectfully urges the Commission to reconsider the use of aeronautical frequencies for In-House BPL and for use by low voltage overhead Access BPL systems. The Commission should also reconsider its decision to employ the 40 dB per decade extrapolation factor in light of the evidence showing that such a factor would often overstate the amount of attenuation obtained at HF frequencies. Additionally, the Commission should reaffirm that notwithstanding the incorporation of mitigation techniques in BPL systems, the obligation to avoid causing harmful interference still obtains. Finally, ARINC urges the Commission to correct certain of the geographic coordinates for aeronautical facilities and to modify the point of contact information for ARINC.

Respectfully submitted,

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[18] ARINC expects that the exclusions incorporated in the Rules and requested herein would largely eliminate any disruption to BPL operations from such a move, yet the possibility would still exist for out-of-band and spurious emissions to impair HF reception.

APPENDIX A

Broadband Over Power Lines (BPL) Interference Analysis

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Abstract

Numerical Electromagnetics Code, Version 4.1 (NEC4) was used to predict near field horizontally polarized field strength and far field radiation patterns of signals radiating in the HF band (2 – 30 MHz) from a 2000 foot span of (13kV or less) medium voltage (MV) electrical transmission line typical of those used to transport Broadband over Power Lines (BPL) signals. Interference potential to high antenna gain, low noise floor, HF ground side receive sites was analyzed. This paper highlights the analysis method and final results.

Introduction

Typical aeronautical mobile (R) HF receive sites are located in areas with environmental noise classifications of QUIET RURAL (-150 dBw/Hz @ 3 MHz), at a minimum, and REMOTE (-163.6 dBw/Hz @ 3 MHz) and are populated with both high gain omni-directional (5 – 6.5 dBi) and very high gain directional (14.5 – 18.2 dBi) HF receive antennas. Received RF signals are routed through low-loss, foam-dielectric, coaxial cable to state-of-the-art, DSP-based, extremely sensitive (-111 dBm 10 dB SINAD sensitivity) receivers to enable international HF Air-to-Ground operators to receive weak signals (just above the environmental noise floor) from distant aircraft on trans-oceanic routes in support of the Federal Aviation Administration's (FAA) oceanic air traffic management program. Any increase to the environmental noise floor, intentional or unintentional, especially from such proximate emitters as MV transmission lines carrying BPL signals, on the aeronautical mobile (R) frequencies would ultimately compromise the FAA's ability to control aircraft in the oceanic airspace by precluding HF operators from receiving weak signals.

Procedure

Field strengths at a fixed height above ground (100 ft) at various distances from a single pair of transmission lines carrying BPL signals in the frequency range 3 to 20 MHz were calculated using NEC4. The MV transmission lines were modeled as a 2000 foot span of 12 sections of two parallel wires 40 ft off the ground, separated by 6 feet with a 3 foot catenary in each section. Each wire segment was loaded as copper with a wire conductivity of 5.8e+7 [mhos/m] and had a radius of 0.25 inches. The span was terminated with R + j0 where R took the values of 6.25, 12.5, 25, 50, 100, 200, 400, and 1000. The MV transmission line was differentially fed with an excitation voltage which was varied with input impedance to produce a consistent 1 mW input power representing an approximate input power spectral density equal to -40 dBm/Hz peak transmitter power across a 9 kHz bandwidth. Average ground properties with conductivity (G) = 0.005 S/m and dielectric constant (k) = 13 were used in the simulation. Analysis was performed at 3, 5, 10, 15, and 20 MHz. Figure 1. Simple MV Power Line Model depicts three of the twelve sections of the MV transmission lines.

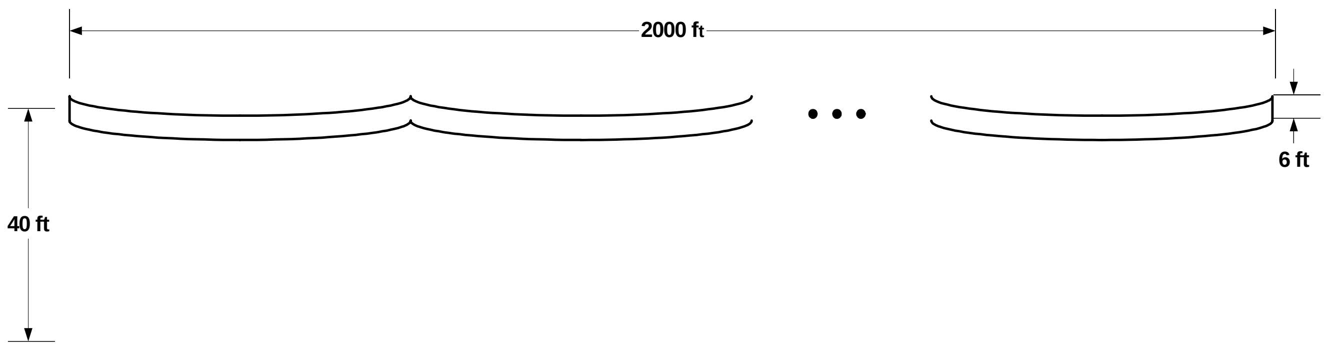

Figure 1. Simple MV Power Line Model

The ground side receive site was represented by a perfectly flat ground and a receive antenna height of 100 feet. The ground side receive antenna was taken to be horizontally polarized. The magnitude of the horizontal component of the electric field, |E|, was calculated at prescribed points at the following distances from the MV transmission lines: D = 100 feet, 200 feet, 500 feet, 1000 feet, 2000 feet, 1 mile (5280 feet), 2 miles, and 5 miles. At distances D = 1000 feet and less, the analysis considered 1000 points between -1000 feet = x = 1000 feet at a height of 100 feet above ground parallel to the MV transmission lines. The transition between the sixth and seventh sections of the parallel transmission lines was represented by x = 0. At distances D of 2000 feet and greater, the analysis considered 360 points of fixed radius r = D offset from the adjacent point by $\Delta\phi = 1°$ around the MV transmission lines at a fixed height of 100 feet above ground. Figure 2, depicts the measurement points.

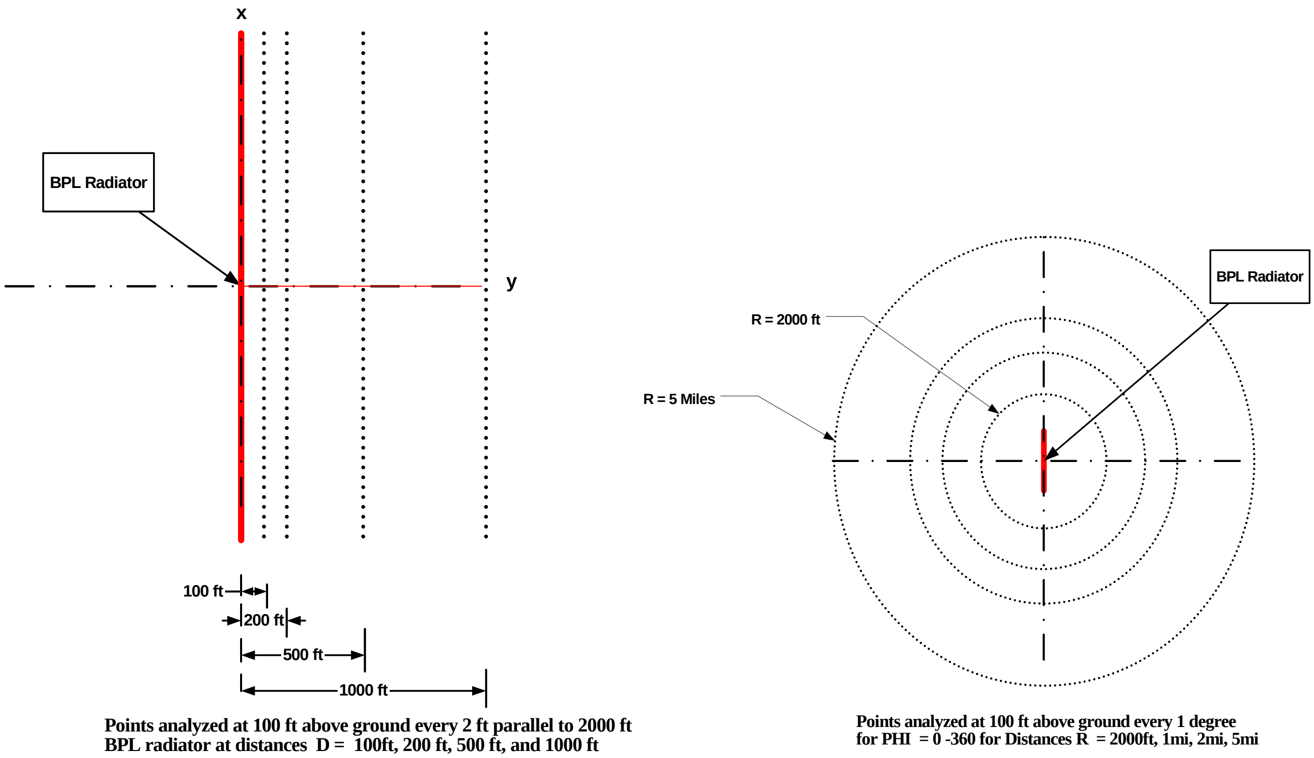

Figure 2. BPL NEC Data Points Analyzed

The calculated magnitude of the horizontal component of the electric field was sorted for maximum field strength in dBμV/m. Additionally, the far field pattern was analyzed to identify the azimuth (ϕ) and elevation (θ) of the maximum power gain (dBi).

Modeling Results

Modeling results showed significant variation in field strength as you move along the radiator for all frequencies analyzed. Swings of approximately 20 dB or more are typical. There was also a 15 to 20 dB variation in overall field strengths as load resistances were varied from 6 ohms to 1000 ohms. Figure 3 shows the predicted field strength at 100 ft from the 5 MHz BPL radiator with a load resistance of 6 and 1000 ohms respectively. A 60 dBμV/m field strength at 100 ft from the BPL radiator is approximately 30 dB over the FCC Part 15 limit of 30 μV/m or 29.542 dBμV/m.

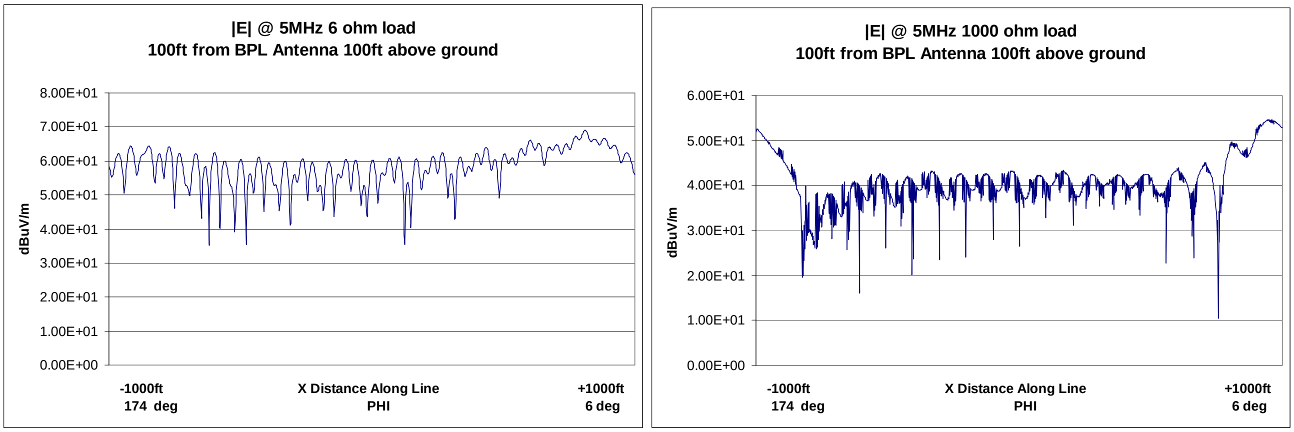

Figure 3. Field Strength Along BPL Radiator at 5 MHz with 6 ohm and 1000 ohm Loads

Analysis showed that as frequency increased, gain also increased. Maximum pattern directivity was consistently at higher elevation angles than the required Part 15 test point elevations. Figure 4, gives the principal plane elevation pattern cuts for both 3 MHz and 20 MHz. Radio sites that have a higher look angle from the BPL radiator will experience larger interfering signal strengths then those at lower look angles. Although not analyzed, higher directivity at higher elevation angles at frequencies 3-12 MHz will contribute to signals received via ionosphere reflection, specifically along Near Vertical Incident Skywave (NVIS) paths.

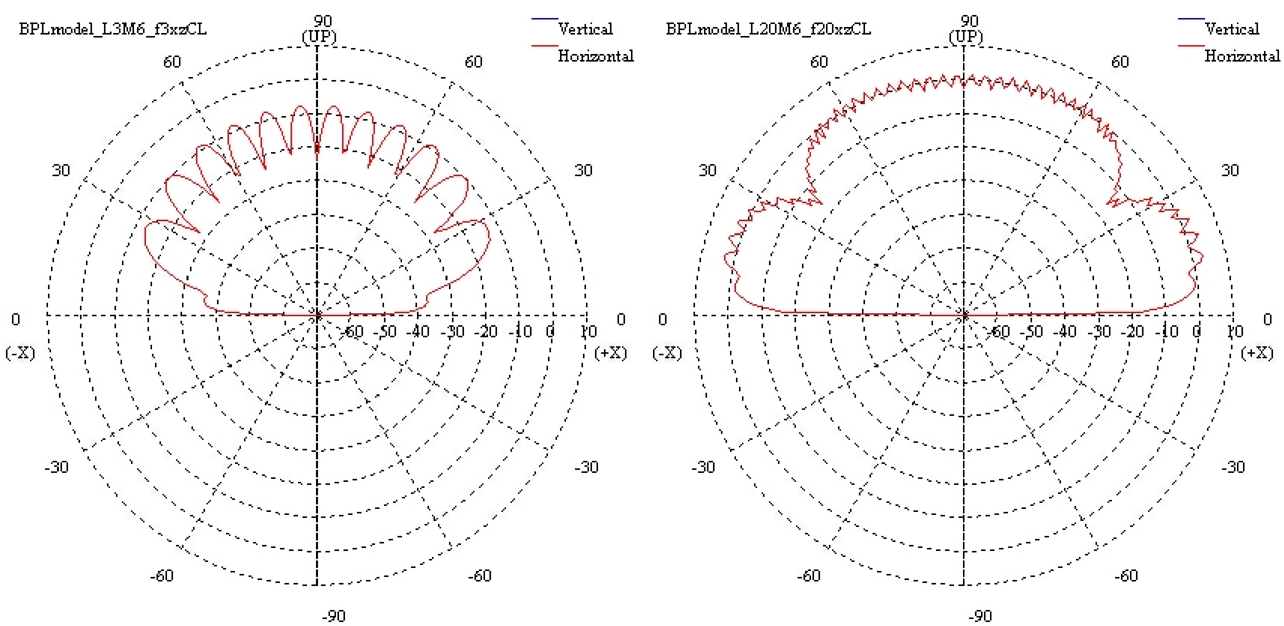

Figure 4. BPL Radiator Principal Plane Patterns @ 3 MHz and 20 MHz

The analysis also showed that the application of an extrapolation factor of 40 dB/decade for signal strength measurements (see FCC Part 15 paragraph 15.31(f)(1) and (2)) is overly optimistic. Figure 5 shows an example of the predicted field strengths from the BPL radiator at 100 ft and 1000 ft respectively. Extrapolation factors are closer to 20 dB/decade although even this is difficult to apply in the real world. The extrapolation factor assumes the actual field measurement is taken at the peak field strength along the radiator. As depicted in Figure 5, the field strength varies more than 20 dB as you move along the radiator. Because the BPL radiator is a physically large radiator, all test measurements will be in the near field region of the pattern. ARINC concludes that applying a general extrapolation factor to a near field measurement to show compliance to the FCC Part 15 specified limit is overly optimistic.

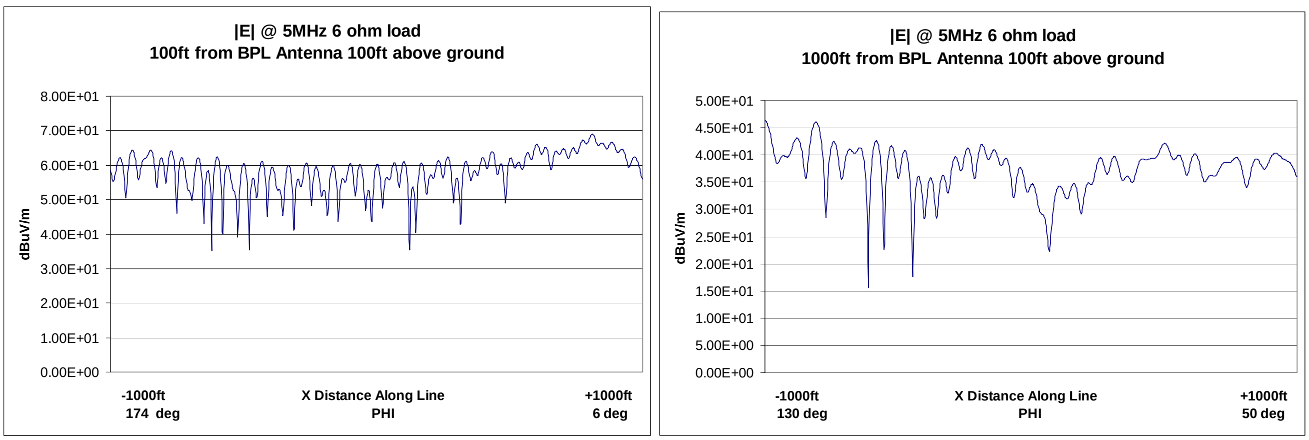

Figure 5. Field strength predicted along BPL radiator at distances of 100ft and 1000ft away

Conclusions

1. It has been demonstrated through computational electromagnetics (CE) simulation using NEC4 and HF engineering analysis, that BPL emissions from representative MV transmission lines result in received interference signal levels well in excess of the FCC Part 15 30 μV/m limit at 30 [m]. Although this simplified model may not represent the BPL system in full, the predictions presented provide estimates that predict significant departures from Part 15 30uV/m limits at 30 meters. As is always the case, the more accurate the simulation, the closer the simulation results will come to real-world situations. Dielectric constant, conductivity, permittivity, and permeability values of the ground plane, and the power line, were all included when possible.

2. The Part 15 40 dB/decade factor is over optimistic by 20 dB or more. A more realistic extrapolation factor may be 15 to 20 dB/decade. This assumes you are measuring a point along the radiator which provides a maximum field strength which is highly unlikely.

3. The pattern data shows a significant variation in received interference signal level as you move along the radiator. Swings of approximately 20 dB or more are typical. It can be concluded that taking a small number of field point measurements (in the near field) and extrapolating to

predict signal strengths farther away from the antenna produces a very low degree of confidence in establishing the real received BPL signal strengths.

4. This analysis considered a ground side receive site situated on perfectly flat ground with a receive antenna of 100ft. Real world installations will provide receive sites that have a significantly higher look angle from the BPL noise source than those investigated here. The BPL radiator exhibits it's highest gain at these higher elevation angles. As a result interference to high sites will be even higher than those predicted here.

5. Skywave propagation was not considered here, but may be significant depending on ionoshperic conditions due to the high angle radiation pattern exhibited by the BPL radiator. Combined signal strengths from multiple BPL sources could dramatically increase the received interference level and should be considered.

References

[1] FCC part 15 "FCC Regulations for Low-Power Non-Licensed Transmitters" July 12, 2004.

[2] G. J. Burke, Numerical Electromagnetic Code – NEC4, Lawrence Livermore National Laboratory, January 1992.